ICE, SNOW AND HOT WATER

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In April of 1969 the Northeast Power Coordinating Council published a map showing the location of eleven new nuclear power plants which are in the planning stage. They are (in New York State) Ginna, Nine Mile Point, J. A. Fitzpatrick, Bell Indian Point #4, Shoreham, Millstone (Conn.), Pilgrim (Mass.), Vernon Yankee (Vermont), Seabrook (New Hampshire) and Maine Yankee (Maine). This planning only emphasizes the fact that our need for electrical power has doubled every ten years since 1900. Our future electrical needs in the United States call for approximately $3x10^{12}$ kwh per year by 1980. About 12% of this power generation will be by nuclear-fueled plants. The use of fossil-fueled plants will continue to rise for several decades to come but percentage-wise, their total output will decrease to less than 25% of this nation's electrical needs by the year 2020 (WRC 1968). Nuclear power will become the prime means of generation unless some other technological accomplishment can provide a cheaper, safer source of power. To generate our expected power needs will require massive amounts of cooling water for both fossil-fueled plants and nuclear-fueled plants.

The fossil-fueled plant operates at about 40% efficiency while the nuclear-fueled plant operates at about 33% efficiency. Thus a nuclear plant releases 2 kw of heat for each kw of electricity generated. Both discharge heated effluent, but the nuclear plant discharges more heat per kwh. The methods of cooling are as follows:

Once through cooling - the water is taken from a nearby source, passes through the cooling cycle and is returned to the source.
Cooling ponds - the source is a constructed pond into which and from which the condenser water passes. Thus the same water is used over and over.
Cooling towers - the cooling water is passed through a tower which cools the water either by evaporative means or radiative exchange. Evaporative means release approximately 1% of the total cooling water to the atmosphere, whereas dry, closed-circuit cooling releases the heat but not the vapor.
Table 1 (WRC 1968) provides an idea of the consumptive use of cooling water by a fossil-fueled plant.

Table 1

Table 1 - Average condenser water requirement and consumptive use for fossil-fueled, steam-electric power plants, 1965-2020

(Gallons per kilowatt-hour)

			Consumptive use	
Year	Condenser requirement[1]	Once through	Cooling Ponds	Cooling towers
1965	40	0.3	0.4	0.5
1980	35	0.2	0.3	0.4
2000	30	0.15	0.25	0.35
2020	25	0.1	0.2	0.3

[1] Based on a design temperature rise of 15° F. in the condenser

North Atlantic Region

The North Atlantic Region as mapped by the Water Resources Council includes all of New England, part of New York, Pennsylvania, Maryland and Virginia, plus Delaware and New Jersey. By 1980, it is expected that this region will be withdrawing about 11×10^9 gallons per day of fresh water and 22×10^9 gallons of saline water per day for steam-electric power. Of this withdrawal 120×10^6 gallons per day of fresh water and 180×10^6 gallons of saline water will be consumed (evaporated) daily. This is equivalent to ten percent of the average daily flow of the Hudson River.

Meteorological Conditions

A 1000mw nuclear plant needs 10^6 gal. min.$^{-1}$ (2500cfs) for cooling purposes. Approximately 1% of the total flow is evaporated, or 10^4 gal. min.$^{-1}$. Table 2 provides data on the volume of air which could be saturated if 10^4 gal. min.$^{-1}$ were released to the atmosphere at the given temperature and relative humidity.

Table 2

	Relative humidity %					
Temp. (°C)	100	95	90	85	80	75
-20	-	76	35	24	18	14
-10	-	31	16	11	8	6
0	-	16	8	5	4	3

Volume in $10^7 m^3$ per min. which theoretically could be raised to saturation by the addition of 10^4 gal. min.$^{-1}$.

Obviously "raised to saturation" and the occurrence of liquid water in that volume are two separate questions. If the volume is raised to saturation and has a liquid water content of 0.3g m^{-3}, then the volume which would be saturated will decrease. Table 3 presents the new calculations.

Table 3

	Relative humidity %					
Temp. (°C)	100	95	90	85	80	75
-20	140	120	100	88	79	70
-10	140	95	76	63	48	42
0	140	76	48	38	30	25

Volume of air ($10^6 m^3$ per min.) which could be saturated and contain 0.3g/m^3 liquid water.

If we now assume that 3% of the added liquid water falls out as snow immediately downwind of the source, a rate of accumulation may be estimated. Allowing for a wind speed which would move the given volume of air past the source each minute and a density ratio of snow to water of 1:10, then one-tenth the numerical values given in Table 3 will give the available cubic centimeter of snow which would fall out. For instance, at -10°C and 95% R. H. $95\times10^5 cm^3$ of snow would be available each minute. Allowing the snow to fall out over a 1km^2 triangular area downwind of the source, the daily snowfall would be approximately 1.3cm. This represents only 3% of the total liquid water content of the saturated volume. Smith (1969) has shown that clouds from a cooling tower may exist for over 20km downwind of the source.

Thermal Pollution vs. Beneficial Use

A 1000 mw nuclear-fueled power generating plant releases 2000 mw of waste heat. Must this be wasted? Or could it be applied for some reasonable usage? If all this heat could be released by dry closed-circuit cooling, it could evaporate all the liquid water in a volume of air ($10^7 m^3$ @ 0.1 gm m^{-3}) and reduce the relative humidity from 100% to 99%, even with a wind of 30km/hr. (Stewart 1969). Any airfield plagued by fog, especially warm fog, would be able to stay above minimum visibility requirement almost all of the time. Similar calculations and experiments have been carried out and reported by Project Warm Fog, etc. 1968.

The discharge of 2000 mw is equivalent to the average incoming solar radiation on an area of $6 km^2$ in mid-New York State. If this were used to heat greenhouses we would maintain a year-round agricultural complex, using the greenhouse as a horizontal cooling tower. Heat consumption would be about 1200 btu per m^2 per hour, or the waste from a 1000 mw plant could heat an area of $0.7 km^2$. Several companies are working on plastic greenhouses, each designed to cover 50 acre tracts of land, at a small fraction of the cost of glass greenhouses. This will make a significant change in the economics of such a complex. The heat can be discharged within the greenhouse year-round. Present experiments at Sonora, Mexico, have shown that the evaporation which takes place inside the greenhouse may condense on the walls at night and may be collected as fresh water for irrigation. (ERL #2).

A more unusual suggestion considers a paper in preparation by Weeks & Campbell (1970) concerning icebergs as a source for fresh water. The paper describes the possibility of transporting icebergs from Antarctic to Australia or the Atacama Desert. After melting, erosion, etc. of the iceberg, it is possible to arrive in Australia with approximately $7.9 \times 10^8 m^3$ of ice. (23×10^{10} gal.) This is equivalent to the cooling water needs of a 1000 mw plant for 160 days. More important, where thermal pollution is a problem, the iceberg could absorb all the discharged heat from such a plant for over a year just to melt it. Obviously this does not apply to the northeast at this time. We don't have very many handy icebergs. It does point out, however, that unusual problems may need unusual solutions. Towing icebergs appears to be economically feasible for certain desert areas. These same areas will need electrical power and a joining of the two ideas may be possible.

If we can melt icebergs then we should consider melting ice in a river or lake. Although I would expect that this would cause some atmospheric problems in the open water area, it may still be worth considering, especially to prevent ice jams which cause floods or bridge damage. Dutton and Bryson have shown that Lake Mendota, Wisconsin, loses a maximum of 323 cal/cm^2 of heat as averaged over one month, November. Allowing for a river surface to cool at this rate, it would be possible to keep an area of $12 km^2$ free of ice. By controlling the mixing of the outflow, this area could be increased.

SUMMARY

The growth of nuclear-fueled power generating plants has brought about a series of problems as well as opportunities. Inadvertent weather modification in the guise of fog, icing and clouds from the thermal discharge will present some hazards, especially in valleys. However, if we learn to use the heat we may be able to heat homes or greenhouses, provide ice-free areas in lakes and rivers or decrease the severity of fog at airports.

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